9. NASA Earth Science and Applications from Space Background Document (SRM #9 "Plan A")

NASA has assembled this document in October 2004to initialize the strategic roadmapping activity. This document describes relevant legacy planning activities and results and is intended to serve as a reference for the Strategic Roadmap (SRM). It was updated in January 2005 to correct typos and reflect the final wording of the objective.

1. Agency Goal and Objective

NASA Goal 5: Study the Earth system from space and develop new space-based and related capabilities for this purpose.

NASA Objective:

- Conduct a program of research and technology development to advance Earth observation from space, improve scientific understanding, and demonstrate new technologies with the potential to improve future operational systems (SRM #9, this roadmap)

Related NASA Objective:

- Explore the Sun-Earth system to understand the Sun and its effects on Earth, the solar system, and the space environmental conditions that will be experienced by human explorers, and demonstrate technologies that can improve future operational Earth observation systems (SRM #10, a related roadmap).

2. Responsible Directorate(s)

Science Mission Directorate

3. External Constituencies

3.1 Evolution of External Relationships: NASA has a broad constituency and web of partnerships for its work in Earth science. While many other agencies are engaged in Earth science, NASA brings the global view from space, providing the global context in which to understand local, regional and global scale change. NASA also brings systems engineering expertise in solving large, complex problems to the daunting challenge of understanding and protecting our home planet.

Over the last two decades NASA has used its "systems" expertise to lead a revolution in the way we study and understand the Earth. *Earth System Science*, the move to an integrated "systems" approach and away from narrow discipline or single-issue research "stovepipes" was the key innovation that revolutionized Earth science. Armed with the recommendations of the 1988 "Bretherton" report, NASA led this revolution with the development of the Earth Observing System.[1] NASA engaged in a deliberate strategy of

[1] Bretherton, F., chair, "Earth System Science, A Closer View," Report of the Earth System Sciences Committee, NASA Advisory Council, January 1988.

supporting interdisciplinary Earth system science research and education as a way of growing this capacity in the nation's research and education communities. The most recent refinement has been to identify science focus areas as key integrating themes that build upon the capabilities of the diverse Earth science disciplines towards an integrated, predictive capacity. Setting long term goals built on the integrated results of broad research questions helps NASA and the community to establish and maintain scientific balance and relevance.

Today, NASA's Earth system science program integrates across the full breadth of science disciplines. Some researchers look at the key physical components of the Earth system (e.g., geologists, oceanographers, atmospheric scientists). Some researchers look at the key biological components of the Earth system (e.g., ecologists, biogeochemists). Some researchers look at the key dynamic processes that cut across the components of the Earth system (e.g., meteorologists, climatologists, biologists, ecologists, hydrologists). Some researchers look at the key impacts of the Earth system on humans and society (e.g., natural hazards and disasters; food and fiber/agriculture, fisheries, and forestry; energy use and management; human health effects). Others look at the key impacts of humans and society on the Earth system (e.g., land cover and land use change; industrial emissions; resource management practices).

NASA is one of a few U.S. government agencies whose mandates are purely for research and technology development, without management or regulatory authority and responsibility. This research independence and NASA's credibility as an unbiased broker of scientific results are important intangible assets that NASA brings to Earth science issues with significant management, policy, and economic implications. In addition, this independent role provides NASA the opportunity to advance the state-of-the-practice in Earth science and transition new capabilities to our management and operational partners in the U.S. government.

3.2 External Constituencies and Corresponding NASA Roles: As a result of this evolution in NASA's research relationships, NASA's Earth system science efforts are at the intersection of five major external constituencies. NASA's current roles reflect these external constituencies:

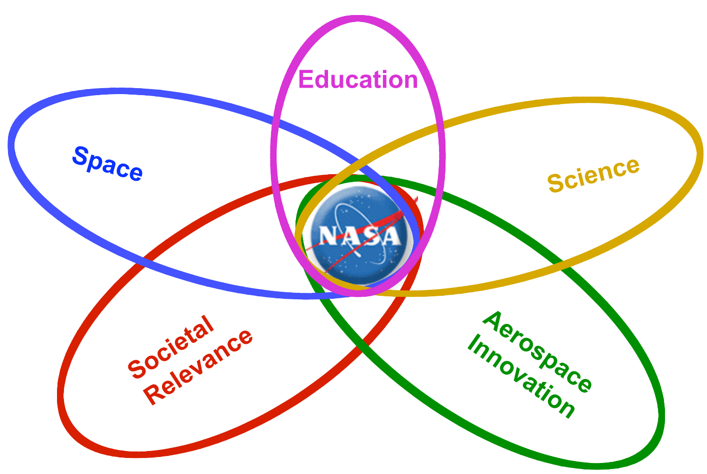

Figure 1: NASA's Major External Constituencies

- **NASA is a Science Agency.** NASA conducts and sponsors research in key arenas where our air and space assets and our complex systems expertise can make defining contributions. NASA is a partner in the larger national and international science community, which is actively engaged in ground and space-based science of all types. NASA science priorities and implementation approaches are broadly reviewed through interagency committees, external advisory groups, and the National Academies.
- **NASA is a Space Agency.** NASA is the leading edge of US civilian research and technology in and about space. NASA shares with the broader space community investments in launch capabilities and facilities, navigation and tracking facilities, etc. NASA coordinates with this broader community through a variety of mechanisms, including the Space Technology Alliance (with the National Security Space Community), the Committee on Earth Observation Satellites (CEOS, representing 41 international space-based Earth observation agencies and organizations), and the International Living With a Star initiative.
- **NASA is an Aerospace Innovation Agency.** NASA collaboratively addresses the technical challenges and develops capabilities to pursue its mission in partnership with the aerospace industry and technology sector. These include the aerospace companies that build our instruments, spacecraft, and supporting technologies as well as the academic researchers who develop new technological capabilities.
- **NASA enhances science, technology, engineering and mathematics education.** NASA addresses its mission to inspire the next generation of explorers through partnerships with the formal and informal education community. These partnerships enable an accessible, dynamic, and engaging learning environment for all citizens. This expands and deepens the Nation's appreciation and understanding of the Earth system and encourages pursuit of scientific and technical careers.
- **NASA's research is relevant to broad national priorities.** NASA conducts cutting-edge research that is relevant to society and human life. NASA's contributions are recognized and coordinated at the highest levels of the US government, such as the Committee on Climate Change Science and Technology Integration (CCCSTI) and the National Science and Technology Council (NSTC). NASA's Earth Science Applications Program is pursuing 12 applications of national priority in collaboration with over a dozen Federal agencies to enable NASA's Earth observations and research to improve the essential services these agencies provide to the Nation. NASA's Earth Science Applications program benchmarks practical uses of NASA-sponsored observations from remote sensing systems and predictions from scientific research and modeling. The approach is to enable the assimilation of science model and remote sensing mission outputs to serve as inputs to established partner agency decision support systems. The outcomes are manifest in enhanced decision support and the impacts are projected to result in significant socio-economic benefits.

NASA's strength is in addressing these overlapping interests. In many ways, the phrase "as only NASA can" in NASA's mission statement refers to these intersections. NASA is a science driven agency that serves the national interest. NASA addresses fundamental questions that inspire and motivate students. NASA is chartered under the space act to advance US leadership in aeronautical and space science and technology. If a NASA activity has compelling science or addresses critical national needs, while at the same time requiring the use of space or advanced aerospace technologies, then that activity is a compelling match to NASA's overall charter, mission, and goals. If the activity can be pursued in a way that inspires and provides educational benefits, the match is even stronger.

3.3 Example Relationships: The following are selected examples of NASA research activities that are directly relevant to major external constituencies.

- The Cabinet-level National Science and Technology Council (NSTC) is the principal means for the President to coordinate science, space, and technology in the diverse parts of the Federal research and development enterprise. An important objective of the NSTC is the establishment of clear national goals for Federal science and technology investments.[2] The Council has four Committees, including the Committee on Environment and Natural Resources (CENR), the Committee on Science, and the Committee on Technology. NASA is an active participant in the NSTC activities related to Earth science, including the Subcommittees on Global Change Research, Ecological Systems, and Disaster Reduction,[3] as well as the Interagency Working Group on Earth Observations.[4]
- NASA is the largest contributor to the U.S. Climate Change Research Program, an interagency program established by the Executive Office of the President to integrate the Congressionally-mandated US Global Change Research Program and the Administration's Climate Change Research Initiative. NASA also participates in the U.S. Climate Change Technology Program. These programs are under the Cabinet-level Committee on Climate Change Science and Technology Integration (CCCSTI), established by the President to provide recommendations on matters concerning climate change science and technology; address related Federal R&D funding issues; and coordinate with Office of Management and Budget on implementing its recommendations.[5]
- NASA is a member of the US Weather Research Program. The USWRP is a partnership among science and operational governmental agencies, and the academic and commercial communities. The broad purpose of the Program is to increase the resiliency of the Nation to weather; that is, to ensure that the federal, state and local governments, the private sector and general public make well-informed and timely weather-sensitive decisions with respect to past, present, and future weather conditions. To achieve this end requires that the scientific and service communities work together to advance weather observing capabilities and

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[2] Web Page, "National Science and Technology Council," accessed Oct. 1, 2004, URL http://ostp.gov/nstc/html/nstc.html

[3] Web Page, "Subcommittee on Natural Disaster Reduction," accessed Oct. 1, 2004, URL http://www.usgs.gov/sndr/

[4] Web Page, "Interagency Working Group on Earth Observations," accessed Oct. 1, 2004, URL http://iwgeo.ssc.nasa.gov/

[5] Web Page, "About the U.S. Climate Change Technology Program," accessed Oct. 1, 2004, URL http://www.climatetechnology.gov/about/index.htm

fundamental understanding of weather and to use this understanding to improve weather prediction and enhance weather services provided to the Nation.[6]

- NASA develops and launches the Nation's weather satellites under a reimbursable agreement with NOAA, and is working with NOAA and DoD on the next generation, converged civilian and military polar-orbiting operational environmental satellite system.
- NASA has about 200 agreements with over 60 foreign nations for Earth science activities, and is active participant in a variety of international research programs and organizations, including the International Geosphere-Biosphere Programme, World Meteorological Organization, the G-8 sponsored Committee on Earth Observing Satellites, and a new international effort to create a Global Earth Observing System of Systems (GEOSS).

<u>4. External Context</u>

4.1 National Policy: NASA's Earth science activities are shaped and influenced by current National Space Policy, current policies on broad access to information, and current Presidential initiatives.

<u>National Space Policy</u>: The Space Act lists "the expansion of human knowledge of the Earth and of phenomena in the atmosphere and space" as the first objective for NASA. NASA has been engaged in scientific remote sensing of the Earth from space from its beginnings as an agency, and this "as only NASA can" role has been affirmed and detailed in succeeding versions of the National Space Policy. [7]

In 2002 the United States Government began a broad review of U.S. space policies to adjust to the domestic and international developments in recent years that affect U.S. space capabilities. [8] The last update of the National Space Policy had been in 1996.[9] To date, the White House has released two major National Space Policy documents, the U.S. Commercial Remote Sensing Space Policy[10] in 2003 and A Renewed Spirit of Discovery[11] in 2004.

- <u>U.S. Commercial Remote Sensing Space Policy</u>. The fundamental goal of U.S. commercial remote sensing space policy is to advance and protect U.S. national security and foreign policy interests by maintaining the nation's leadership in remote sensing space activities, and by sustaining and enhancing the U.S. remote sensing industry. Doing so will also foster economic growth, contribute to

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[6] Terms of Reference for the U.S. Weather Research Program (2001), URL http://box.mmm.ucar.edu/uswrp/program_organization/tor.html

[7] U.S. Public Law, "The National Aeronautics and Space Act of 1958," Public Law number 85-568, as Amended, URL http://www.hq.nasa.gov/ogc/spaceact.html,

[8] As recommended, for example, by "The Report of The Commission to Assess United States National Security Space Management and Organization," pursuant to Public Law 106-65, the Honorable D. Rumsfeld,, chair, January 11, 2001, URL http://www.defenselink.mil/pubs/space20010111.html

[9] The White House, National Science and Technology Council "Fact Sheet, National Space Policy," September 19, 1996, URL http://www.ostp.gov/NSTC/html/fs/fs-5.html. The actual policy statement is classified, and only this fact sheet is publicly available.

[10] White House Fact Sheet, "U.S. Commercial Remote Sensing Space Policy," May 13, 2003, URL http://www.whitehouse.gov/news/releases/2003/05/20030513-8.html

[11] White House Web Page, "President Bush Announces New Vision for Space Exploration Program," URL http://www.whitehouse.gov/infocus/space/index.html

environmental stewardship, and enable scientific and technological excellence. This policy requires that NASA:

- Rely to the maximum practical extent on U.S. commercial remote sensing space capabilities for filling imagery and geospatial needs.
- Focus U.S. Government remote sensing space systems on meeting needs that cannot be effectively, affordably, and reliably satisfied by commercial providers because of economic factors, civil mission needs, national security concerns, or foreign policy concerns.
- Develop a long-term, sustainable relationship between the U.S. Government and the U.S. commercial remote sensing space industry.

- A Renewed Spirit of Discovery: On January 14, 2004, President Bush announced a new vision for the Nation's space exploration program. The President committed the United States to a long-term human and robotic program to explore the solar system, starting with a return to the Moon that will ultimately enable future exploration of Mars and other destinations. The benefits of space technology are far-reaching and affect the lives of every American. Space exploration has yielded advances in communications, weather forecasting, electronics, and countless other fields.

National Policies on Broad Access to Information: Providing access to information and observations about the Earth is a fundamental responsibility for NASA under both the Space Act and the President's Management Agenda.

- One of NASA's functions as listed in the Space Act is to "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." NASA's Earth Observing System Data and Information System provides over 29 million data products in response to 2.1 million queries each year.
- Within the President's Management Agenda, Expanded Electronic Government is one of the five government-wide goals to improve federal management and deliver results that matter to the American people. [12] Geospatial One Stop is an intergovernmental project in support of the President's Initiative for E-government. Geospatial One Stop builds upon its partnership with the Federal Geographic Data Committee (FGDC) to improve the ability of the public and government to use geospatial information to support the business of government and facilitate decision-making.[13] As a major source of Earth observations, NASA is one of the 19 member agencies in the FGDC established under OMB Circular A-16.[14] NASA's Distributed Active Archive Centers (DAACs) and Research, Education and Applications Solutions Network (REASoN) projects contribute to the U.S. capacity for data management of Earth observations. NASA is

[12] The Executive Office of the President, Office of Management and Budget, "The President's Management Agenda," Fiscal Year 2002, URL http://www.whitehouse.gov/omb/budget/fy2002/mgmt.pdf
[13] Web Page, "National Spatial Data Infrastructure, Geospatial One-Stop," URL http://www.geo-one-stop.gov/
[14] "OMB Circular A-16, Revised," August 19, 2002, URL http://www.whitehouse.gov/omb/circulars/a016/a016_rev.html

recognized for the Geospatial interoperability and participation in the OpenGIS Consortium and the FGDC.[15]

Presidential Initiatives: NASA has a critical role in implementing *three* major Presidential directives or initiatives:

- Climate Change Research Initiative;
- U.S. Integrated Earth Observation System; and
- Vision for Space Exploration.

NASA's Earth science programs are *essential* to the success of the first two, and will surely prove to be so to the third. NASA's contributions to the Earth sciences are unique, numerous, and critically important to future efforts to protect life and property, facilitate responsible environmental stewardship, and understand and predict the dynamic earth system.

4.2 International Context: Building upon the results of the 2002 World Summit on Sustainable Development,[16] the G-8 Leaders agreed at the Evian Summit in 2003 on an Action Plan on Science and Technology for Sustainable Development.[17] The Plan builds on U.S. initiatives to develop transformational technologies in three areas: energy, agriculture, and global observation.[18] In a recent summary of progress on the implementation of these agreements, the White House reported the holding of the First and Second Earth Observation Summits (EOS) and adoption of the Framework document on a Global Earth Observation System of Systems (GEOSS), as well as the plan to adopt a final 10-year strategic implementation plan on GEOSS at Third EOS in 2005 and the work to identify the international mechanism to provide coordination and oversight for GEOSS.[19] Fifty-three nations now participate in the *ad hoc* Group on Earth Observations that is preparing the GEOSS 10-year Plan. Strengthening international co-operation on global Earth observation is on the world's agenda.

Nearly all of NASA's Earth science missions have substantial international participation, ranging from simple data sharing arrangements to ground validation to provision of instruments, satellite buses and launch services for space missions. We participate in the UNEP/WMO Triennial Ozone Assessment, the World Climate Research Program, the International Geosphere/Biosphere Programme, and the International Human Dimensions of Global Change Programme (IHDP). NASA scientists individually are key contributors

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[15] Web page, "NASA Contributions to GEO and IWGEO," accessed Oct. 6, 2004, URL http://earth.nasa.gov/visions/geoss.html

[16] United Nations, "Report of the World Summit on Sustainable Development, Johannesburg, South Africa, 26 August-4 September 2002," A/CONF.199/20*, Pg. 63, URL http://ods-dds-ny.un.org/doc/UNDOC/GEN/N02/636/93/PDF/N0263693.pdf

[17] Summit Documents Web Page, "Science and Technology for Sustainable Development - A G8 Action Plan," Accessed Oct. 4, 2004, URL http://www.g8.fr/evian/english/navigation/2003_g8_summit/summit_documents/science_and_technology_for_sustainable_development_-_a_g8_action_plan.html

[18] White House Science and Technology Fact Sheet, "Fact Sheet: Action on Science and Technology," June 2, 2003, URL http://www.whitehouse.gov/news/releases/2003/06/20030602-15.html

[19] White House Web Page, "Science and Technology for Sustainable Development: "3r" Action Plan and Progress on Implementation," June 10, 2004, URL http://www.whitehouse.gov/news/releases/2004/06/20040610-53.html

to the assessment reports of the Intergovernmental Panel on Climate Change (IPCC), which conducts a quadrennial assessment of the state of knowledge of climate change. The IPCC was initiated under the United Nations Framework Convention on Climate Change in 1992. NASA's wide range of international partnerships is documented in the publication "Global Reach", prepared by the Office of External Relations. NASA participates in the Millennium Ecosystem Assessment through the provision of satellite data and the involvement of individual scientists.

5. Inter-Roadmap Dependencies

Given the role of the Sun in driving the Earth's weather and climate system and the role of the Earth's magnetic field in shielding the Earth from the solar wind, Strategic Roadmaps #9 and #10 will be inter-dependent, and strong ties will be formed between the two Roadmap development committees. Earth is a planet, and the work guided by the extra-terrestrial exploration roadmaps (#1 through #4) will benefit from and relate to that guided by roadmaps #9 and #10. Earth science results from the work guided by Roadmap #9 will also feed into the Education Roadmap (#12).

In addition, this Roadmap will be dependent upon technologies and capabilities guided by the following Capability Roadmaps:

- High-capacity telecom/information transfer (#5)
- Autonomous systems/robotics (#10)
- Scientific instruments/sensors (#12)
- Advanced modeling/simulation (#14)
- System engineering/cost/risk analysis (#15)

6. Roadmap Development Plan

6.1 Approach: Science naturally progresses from characterization, to understanding, to prediction. The scientific method consists of recognizing a science challenge, hypothesizing the underlying mechanisms, making testable predictions based upon the hypothesis, and validating the results through experimentation and further observation.

The following figure shows this progression for Earth science. To guide its research program, NASA in consultation with the science community has identified 24 key science questions (see Table 2 for a summary graphic, the full wording of these science questions is available in the Research Plan[20]). These 24 questions range from characterizing variability to predicting future system responses. These are not static; they will evolve over time commensurate with scientific progress.

[20] NASA, "Understanding Earth System Change: NASA's Earth Science Enterprise Research Strategy for 2000-2010," December 2000, available through URL http://www.earth.nasa.gov/visions/researchstrat/Research_Strategy.htm. A DRAFT update to this document, "Earth Science Research Plan, 1/6/05 DRAFT," will be made available to the Strategic Roadmap Committee and the public.

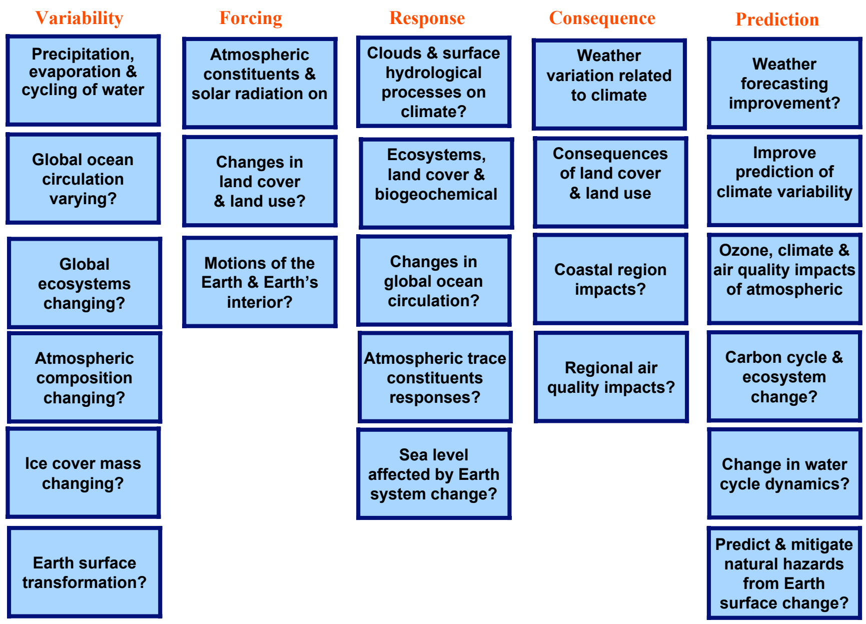

Figure 2: Twenty-Four Earth System Science Research Questions, from Understanding Variability to Enabling Prediction.

Earth System Science is a highly integrated interdisciplinary field of research, and these research questions are tightly coupled. NASA has organized this research around six science focus areas that correspond to the six prediction science questions in the table above. Enabling predictive results requires that all of these science questions be addressed. Focusing on the capstone of scientific research, predictive results, provides the framework for assessing investments and priorities in a way that is both science-driven and results-oriented. This avoids observation-driven or mission-centric planning. The current six science focus areas are:

- Atmospheric Composition
- Carbon Cycle & Ecosystems
- Climate Variability & Change
- Water and Energy Cycle
- Weather
- Earth Surface and Interior

Each Science Focus Area has a team of NASA and Principal Investigators from outside the Agency that plans and implements a roadmap for the focus area. These roadmaps are built along an ascending "staircase" of knowledge steps required to achieve the Focus Area goals over a decadal timeframe. Associated with each knowledge step are basic research, satellite observations, field campaigns, required technologies, and modeling efforts. The ascent is punctuated by periodic scientific assessments, some required by international convention, to define the state of knowledge at that point in time for use in policy-making.

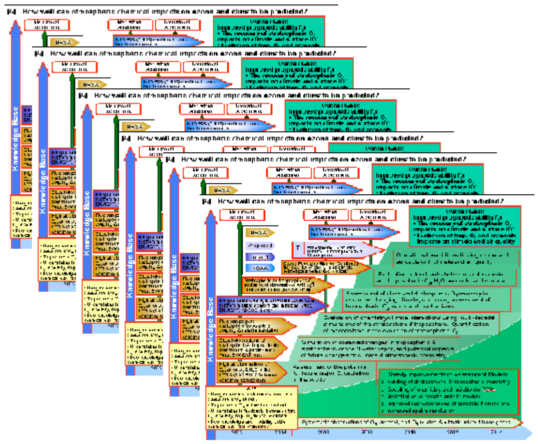

Figure 3: Six Earth System Science Focus Area Roadmaps, building towards Predictive Results.

Roadmaps for each of the six focus areas are updated annually in support of the budget process, with periodic wholesale review and update as a function of focused community review.[21] For example, NASA chartered the Solid Earth Science Working Group led by an Earth System Science and Applications Advisory Committee (ESSAAC) member and comprising largely external community scientists to define the priorities for NASA in this area in the near, mid and long term. The report of this group was recently reviewed by the NRC. It forms the basis for roadmap refinement and implementation in this Focus Area. An analogous group is being formed for Atmospheric Composition.

These Science Focus Area roadmaps are the basis for defining requirements and roadmaps for advanced technology development. They are also the basis for planning the future of the Earth Science Applications Program. The Applications Program (now the Applied Sciences program in the new Sun-Earth System division of the Science Mission Directorate). Roadmaps for each of its twelve applications of national priority are developed and matured with the partner U.S. government agencies with the appropriate management or regulatory mandate.[22] The current set of twelve are:

Table 1: Twelve Applications of National Priority

Agricultural Efficiency	Ecological Forecasting
Air Quality	Renewable Energy
Aviation	Homeland Security
Carbon Management	Invasive Species
Coastal Management	Public Health
Disaster Management	Water Management

6.2: Role of FACA Advisory Committees & Ad hoc Panels: In the mid-1980s, the "Bretherton Report" of the NASA Advisory Council laid out the vision of Earth System Science, breaking down the barriers between traditional disciplines such as oceanography

[21] See URL http://www.earth.nasa.gov/roadmaps/index.html for the previous versions of the roadmaps. The update to the science research plan, "Earth Science Research Plan, 1/6/05 DRAFT," contains updated versions of these 10-year roadmaps.
[22] NASA Office of Earth Science, "Earth Science Applications Plan," July 2004, URL http://www.earth.nasa.gov/visions/AppPlan.pdf. The most recent versions of the Applications Roadmaps are on pages 36 to 61.

and geology to enable a systems approach to understanding our planet.[23] This new vision revolutionized Earth science and led to the current Earth Observing System (EOS).

In the late 1990s, as NASA was approaching the completion of the initial set of EOS missions, NASA undertook a public discussion on the future observing strategy. NASA conducted a Request for Information to solicit broad community input followed by a community workshop.[24] NASA also solicited Advisory Committee and National Academy Review,[25] developed measurement concepts in order to estimate the budget requirements, and cleared the implied cumulative funding with the White House before publishing the collection of documents that make up the research strategy for the next ten years.[26] An update to this document organizing the research around the six science focus areas is under development.

With the identification of the Science Focus Areas, NASA began a process of external reviews organized around these areas. The result of this first effort is the report "Living on a Restless Planet.[27] The next planned external review will be of the Atmospheric Composition Focus Area.

The Earth System Science and Applications Advisory Committee (ESSAAC) of the NASA Advisory Council meets twice each year to review plans and roadmaps in this area.[28] Its Technology and Information Systems subcommittees guide planning efforts in these essential enabling activities.

Occasional ad hoc panels of community experts are convened to review plans and propose future courses of action. Examples include science and technology discipline workshops, the Biennial Reviews and Easton Workshops of the late 90s, and the interagency Weather Research Program and various National Science and Technology Council committees and subcommittees. Many program elements and project conduct annual investigator meetings to assess progress and plan future activities.

NASA has asked the NRC to conduct a Decadal Survey for Earth System Science taking a fresh look at the science and research issues since the original "Bretherton report" of the NASA Advisory Council in the mid-1980s.

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[23] Bretherton, F., chair, "Earth System Science, A Closer View," Report of the Earth System Sciences Committee, NASA Advisory Council, January 1988.

[24] NASA, "Report of the Workshop on NASA Earth Science Enterprise Post-2002 Missions," March 3, 1999.

[25] Committee on Global Change Research, "Global Environmental Change: Research Pathways for the Next Decade," National Academy Press, 1998, available through URL http://www.nap.edu/catalog/6264.html. The National Academy sometimes reviews NASA's Earth system science programs as part of larger national efforts. Such was the case with this 1998 "pathways" report, which addressed decadal recommendations for the U.S. Global Change Research Program. This was essentially a decadal assessment of NASA's research in the context of the larger, national program.

[26] NASA, "Understanding Earth System Change NASA's Earth Science Enterprise Research Strategy for 2000 - 2010," December 2000, URL http://www.earth.nasa.gov/visions/researchstrat/Research_Strategy.htm. An updated research plan is under development, and our intent is to provide this in draft form to the Strategic Roadmap Team.

[27] Solid Earth Science Working Group, "Living on a Restless Planet," 2002, available through URL http://solidearth.jpl.nasa.gov/PAGES/report.html

[28] See URL http://www.earth.nasa.gov/visions/ESSAAC_minutes.html for more information.

6.3: Stakeholder Outreach Strategy: Stakeholder outreach is conducted through several pathways, such as: multilateral and bilateral meetings with sibling agencies; special sessions at the American Geophysical Union (AGU),[29] American Meteorological Society (AMS),[30] the International Geoscience and Remote Sensing Symposium (IGARSS) [31] and Ecological Society of America (ESA)[32] conferences; annual technology conferences conducted by the Earth Science Technology Office;[33] and focused presentations at a wide variety of national and international scientific and environmental conferences. The Earth Science Technology Office (ESTO) also maintains a publicly accessible database that documents how science needs relate to measurement scenarios that translate to specific technology requirements.[34] Annual workshops open to U.S. industry, academia, federally funded research and development centers, and U.S. government organizations, help keep this database relevant and up-to-date.[35]

In the spring of 2000 NASA held a series of workshops (including one public workshop) on the long-term, future vision for Earth science. Based on these workshop results, a NASA internal steering group coordinating the efforts of workgroups made of NASA and academic participants, and developed the "Earth Science Vision 2030 Working Group Report."[36] This report received limited, external review by selected members of the academic community before its release. This effort proceeded in parallel with the development of the Science Focus Areas, and does not reflect this approach to organizing and prioritizing NASA's research investments. The report is not NASA's "official" policy or position on the future of Earth science, but is a step towards a community discussion on the future of Earth system science from space.

The Request for Information and community Workshop on NASA Earth Science Enterprise Post-2002 Missions is a past example of broad community outreach for innovative mission approaches.

Stakeholder outreach is also conducted at the interagency level, coordinated at the White House level. For example:

- In July 2003, Energy Secretary Abraham, Commerce Secretary Evans, and White House Office of Science and Technology Policy Director Marburger released the Strategic Plan for the U.S. Climate Change Science Program, to guide activities

[29] See URL http://www.agu.org/, for more information.
[30] See URL http://www.ametsoc.org/ for more information.
[31] See URL http://www.ewh.ieee.org/soc/grss/igarss.html for more information.
[32] See URL http://www.esa.org for more information.
[33] See for example URL http://www.esto.nasa.gov/conferences/estc2004/ for information about the fourth annual Earth Science Technology Conference. To encourage greater participation, these annual conferences alternate between the East and West coasts.
[34] See URL http://estips.gsfc.nasa.gov/ for access to the Earth Science Technology Integrated Planning System (ESTIPS).
[35] See for example "Sensor & Platform Technology Requirements for Implementing NASA's Earth Science Research Strategy in the Next Decade: A Summary Report Based on the ESTO Technology Planning Workshop Held on March 5-6, 2003," available on the Web at URL http://estips.gsfc.nasa.gov/Home/docs/ESTOWorkhop20031.pdf
[36] NASA Report, "Earth Science Vision 2030 Working Group Report," March 2004, URL http://neptune.gsfc.nasa.gov/vision/Earth_Science_Vision_2030.pdf

and priorities of the CCSP over the next decade.[37] The plan was developed with extensive consultation with the scientific community, including a 1,300-person workshop hosted by CCSP in November 2002, with representatives from over 35 countries. The National Academies of Science gave the plan high marks as it "articulates a guiding vision, is appropriately ambitious, and is broad in scope. It encompasses activities related to areas of long-standing importance, together with new or enhanced cross-disciplinary efforts." NASA is a key player in climate change science and research.

- The 15 Agency Interagency Working Group on Earth Observations (IWGEO) conducted a public meeting in June 2004, released the DRAFT Strategic Plan for the U.S. Integrated Earth Observation System for public comment in September, 2004, and is planning a second public meeting for January 2005.[38]

6.4 Role of NASA Centers: The NASA Centers are the engines of progress in Earth science.

- The Goddard Space Flight Center (GSFC) is a world capital of Earth system science, conducting a wide variety of leading edge disciplinary research and pioneering the interdisciplinary approach to studying the Earth as a system. GFSC's subsidiary Goddard Institute for Space Science (GISS) is a world leader in the first use of new observations and process understanding in global and regional models of climate change.
- The Jet Propulsion Laboratory (JPL) is a pioneer in Solid Earth science and Physical Oceanography, and a leading supplier of new scientific remote sensing instruments.
- The Ames Research Center (ARC) is a leader in life sciences and information technology for research, and has recently acquired the world's largest supercomputing capability which GSFC and JPL scientists can use to run large Earth science simulations.
- The Dryden Flight Research Center (DFRC) operates suborbital science platforms and leads the acquisition of next-generation suborbital and unpiloted air vehicle platforms.
- The Langley Research Center (LaRC) contributes scientific expertise in areas of the Earth's radiation balance and atmospheric composition and chemistry.
- The Stennis Space Center (SSC) provides system engineering of selected Earth science applications.
- The Marshall Space Flight Center (MSFC) brings expertise in short-term weather prediction and creation of long-term temperature records from satellite instruments.

7. Key Milestones

The following are the key milestones under the presently planned schedule. These will be updated to reflect the planning for the Strategic Roadmap development.

[37] For access to the plan and the NRC review, please see the "Strategic Plan for the Climate Change Science Program" web page at URL http://www.climatescience.gov/Library/stratplan2003/default.htm

[38] See URL http://iwgeo.ssc.nasa.gov/ for more information.

[xx] See URL http://www.esa.org/ for more information

Complete deployment of EOS 1st series	June 2004
Project Columbia initial deployment	Oct 2004
Updated Research Plan	Dec 2004
GEOSS 10yr Implementation Plan	Jan 2005
Decadal Survey phase 1 report	Spring 2005
IPCC 3rd Assessment report	Summer 2005
Decadal Survey phase 2 report	Summer 2006

8. Key NASA Documents

1. *A Journey to Inspire, Innovate, and Discover*, June 2004 (the Aldridge Commission Report).
2. *The Need to Transform the Structure and Management of NASA*, Report of the Roles, Responsibilities And Structures ("Clarity") Team, June 24, 2004.
3. *A Renewed Commitment to Excellence*: An Assessment of the NASA Agency-wide Applicability of the Columbia Accident Investigation Board Report, January 30, 2004 (the Diaz Report).
4. *The Columbia Accident Investigation Board Report*, 2003 (the CAIB report)
5. *Earth Science Enterprise Strategy*, October 1, 2003.
6. *Earth Science Research Plan* (complete revision of 2000 edition in process)
7. *Earth Science Applications Strategy*, September 2004
8. *Strategic Plan for the US Climate Change Science Program*, 2003
9. *Living on a Restless Planet: Report of the Solid Earth Science Working Group,* 2003.
10. *Enhancing Mission Success -- A Framework for the Future*, A Report by the NASA Chief Engineer and the NASA Integrated Action Team, January 2001.

9. NRC Bibliography (Past 5 Years)

1. Steps to Facilitate Principal Investigator-Led Earth Science Missions (NRC, 2004)
2. Assessment of NASA's Draft Earth Science Enterprise Strategy (NRC, 2003)
3. Enhancing NASA's Contribution to Polar Science (NRC, 2001)
4. Review of NASA's Earth Science Enterprise Research Strategy for 2000-2010 (NRC, 2001)
5. Assessment of the Usefulness and Availability of NASA's Earth and Space Science Mission Data (NRC, 2002)
6. Transforming Remote Sensing Data into Information and Applications (NRC, 2001)
7. Toward New Partnerships in Remote Sensing (NRC, 2002)
8. Using Remote Sensing in State and Local Government (NRC, 2003)
9. Review of NASA's Earth Science Enterprise Applications Program Plan (NRC, 2002)
10. The Role of Small Satellites in NASA and NOAA Earth Observation Programs (NRC, 2002)
11. Report of the Task Group on Assessment of NASA Plans for Post-2002 Earth Observing Missions (NRC, 1999)
12. Review of NASA's Distributed Active Archive Centers (NRC, 1998)
13. Utilization of Operational Environmental Satellite Data: Ensuring Readiness for 2010 and Beyond (NRC, 2004)

14. Satellite Observations of the Earth's Environment (NRC, 2003)
15. The Science of Regional and Global Change: Putting Knowledge to Work (NRC, 2001)
16. Improving the Effectiveness of U.S. Climate Modeling (NRC, 2001)
17. Global Air Quality: An Imperative for Long-Term Observational Strategies (NRC, 2001)
18. Issues in the Integration of Research and Operational Satellite Systems for Climate Research I. Science & Design (NRC, 2000)
19. Issues in the Integration of Research and Operational Satellite Systems for Climate Research II. Implementation (NRC, 2000)
20. Down to Earth: Geographic Information for Sustainable Development in Africa (NRC, 2002)
21. From Research to Operations in Weather Satellites and Numerical Weather Prediction – Crossing the Valley of Death (NRC, 2000)
22. Global Environmental Change: Research Pathways for the Next Decade (NRC, 1998)
23. Our Common Journey (NRC, 1999)

10. Appendix – Selected Key Participants

Review of Earth Science Focus Area roadmaps has been conducted by the Earth System Science and Applications Advisory Committee. In addition, each of the Science Focus Area managers works with representatives of the external science community. Those currently engaged are listed below.

ESSAAC Members 2003-04

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Dr. Joyce E. Penner	University of Michigan
Dr. A. Scott Denning	Colorado State University
Dr. Jack Dangermond	President, ESRI
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Dr. Melba M. Crawford	Department of State (Fellow from U. Texas)
Dr. Eric J. Barron	Pennsylvania State University
Dr. Kenneth C. Jezek	Ohio State University
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Dr. George David Emmitt	Simpson Weather Associates
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Dr. John Townshend	Univ of Maryland
Dr. Ethan Schreier	Associated Universities, Inc
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Dr. Jeremy Bloxham	Harvard
Dr. Patrick Mantey	UC Santa Cruz
Mr. Thomas Holm	USGS EROS Data Center
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John Townshend,	University of Maryland

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Dr. Yi Chao,	(JPL

Dr. Don Cline	(NOAA)
Dr. Roger Davies	(JPL)
Dr. JC Duh	(JPL)
Dr. Dara Entekhabi	(MIT)
Dr. Jared Entin	(NASA HQ)
Dr. Paul Houser	(GSFC)
Dr. Tom Jackson	(USDA)
Dr. Mike Jasinski	(GSFC)
Dr. Ramesh Kakar	(NASA HQ)
Dr. Randy Koster	(GSFC)
Dr. Bill Lapenta	(MSFC)
Dr. Dennis Lettenmaier	(U. of Washington)
Dr. Bing Lin	(Langley)
Dr. Eni Njoku	(JPL)
Dr. Michele Rienecker	(GSFC)
Dr. Bill Rossow	(GISS)
Dr. Robert Schiffer	(UMBC)
Dr. Adam Schlosser	(GSFC then MIT)
Mr. Greg Stover	(Langley)
Mr. David Toll	(GSFC)
Dr. Bruce Wielicki	(Langley)
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Solid Earth Science Working Group

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